

In-situ Thermal Treatment of Trichloroethene at Marshall Space Flight Center

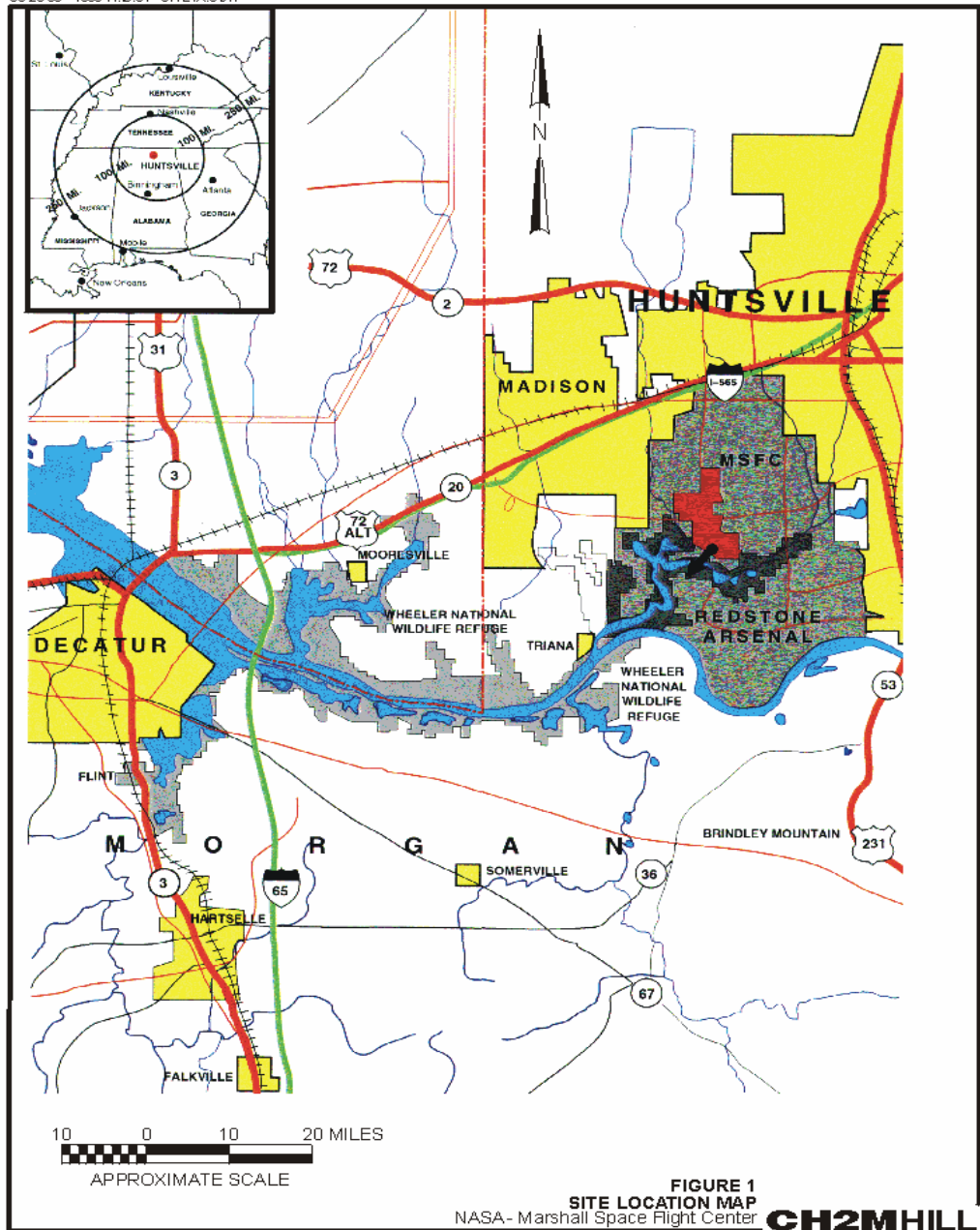
Jason Cole, William J. McElroy, Jason Glasgow (CH2M HILL, Inc.)

Gorm Heron, Jim Galligan, and Ken Parker (TerraTherm, Inc., Fitchburg, MA)

E.F. Davis (NASA Marshall Space Flight Center, Huntsville, AL)

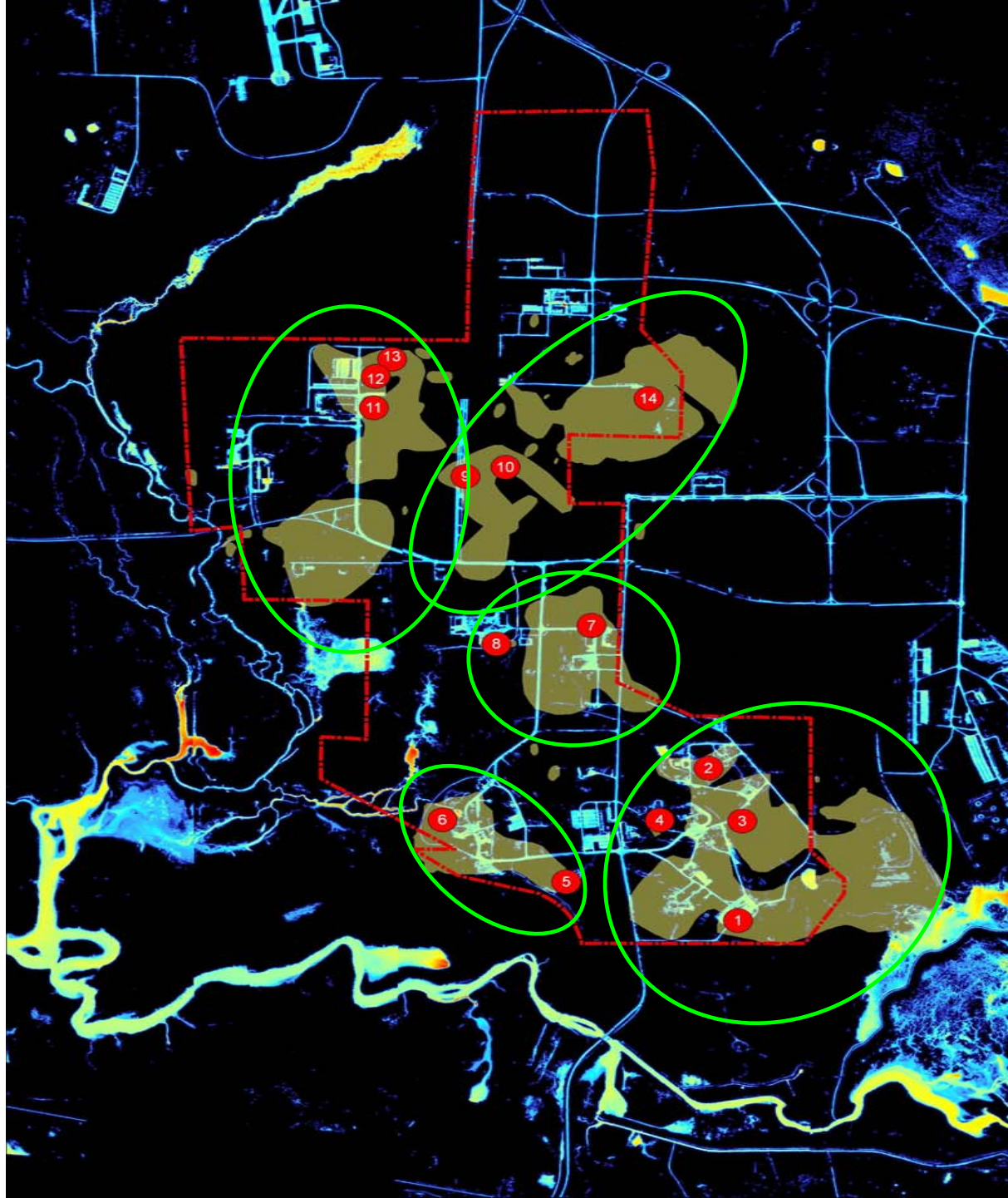
Background 1

- Marshall Space Flight Center (MSFC) is the principle propulsion development center for the National Aeronautics and Space Administration (NASA).
 - Located in Huntsville, Alabama MSFC covers ~1,800 acres within the boundary of Redstone Arsenal (U.S. Army).
 - 79 sites regulated under the Comprehensive Environmental Resource Conservation and Liability Act (CERCLA).
 - Groundwater has been integrated into one operable unit (OU-3)
- Groundwater Strategy
 - Identify contaminant sources, contributing sites or activities;
 - Characterize major groundwater plumes;
 - Eliminate / Reduce Source Areas; and
 - Monitor to verify treatment effectiveness and continued compliance with regulatory framework.
- [REFERENCE GRAPHIC LOCATOR MAPS]



Background 2

- Five major groundwater plumes and 15 “hot spots” have been identified
- Chlorinated solvents are the dominant contaminants site wide; trichloroethylene (TCE) is the most abundant and widespread
- Treatability study program initiated to:
 - assess degree of in-situ technology effectiveness
 - reduce uncertainties in future OU-3 feasibility study
- Study area selection:
 - Screen source area contaminants
 - Identify potentially applicable in-situ treatment technologies
 - Develop numeric ranking to select study areas and technologies
- [REFERENCE THERMAL IMAGRY]

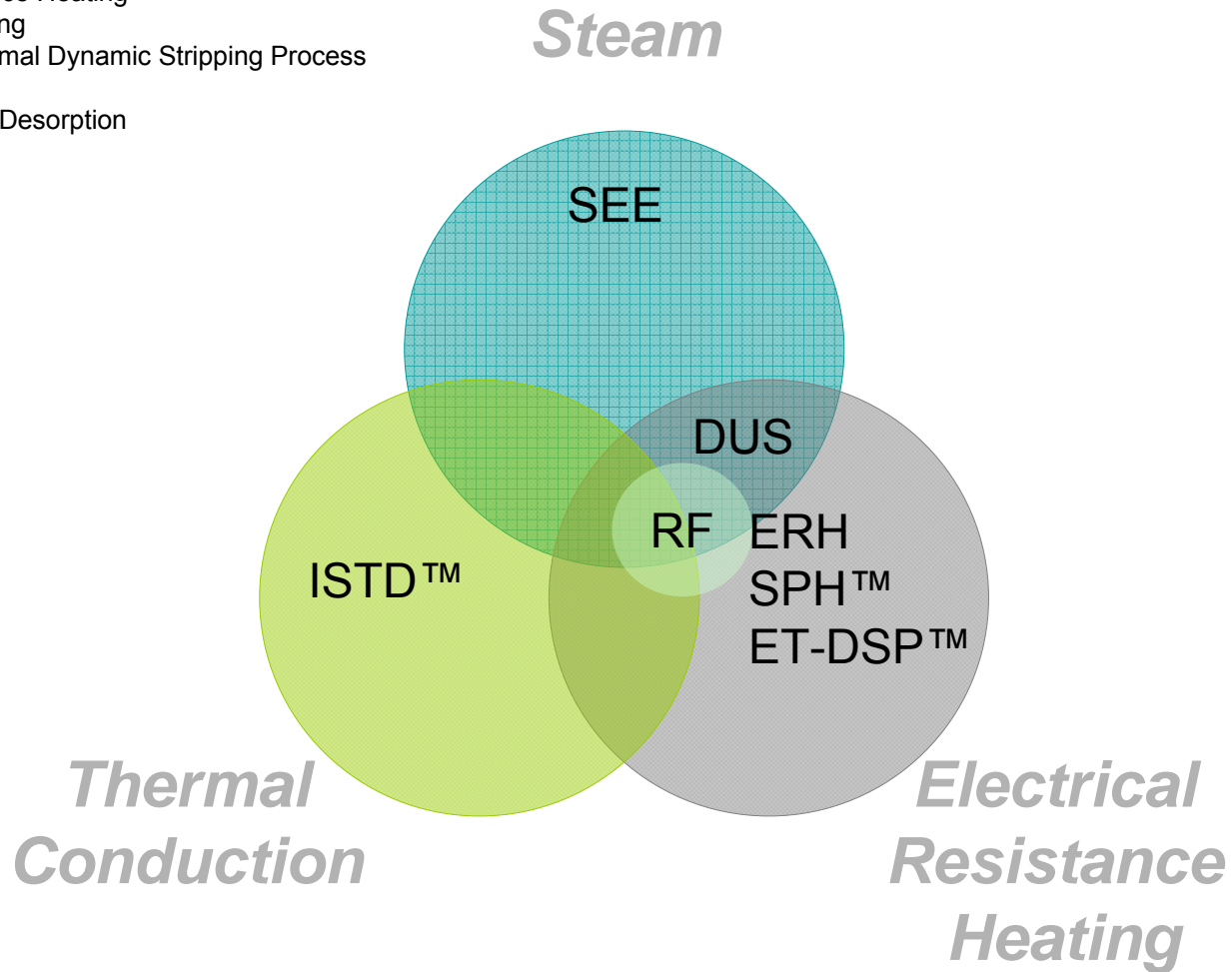


Source Area -13

- Source Area-13 (SA-13) was one of four study areas selected.
- SA-13 history and investigation results indicate that a former drum storage pad area outside of building 4705 was the likely source area of contaminants.
 - TCE is the primary soil and groundwater contaminant
 - Presence of dense non-aqueous phase liquid (DNAPL) suspected:
 - TCE soil concentrations ≥ 260 mg/kg and groundwater $\geq 11,000$ $\mu\text{g/l}$
- In-situ technologies selected for evaluation:
 - In-situ chemical oxidation (ISCO)
 - In-situ Thermal Treatment (ISTT)
- Treatment at SA-13 by ISCO had limited effectiveness.
- On the basis of the ISCO results, NASA made the decision to evaluate ISTT at SA-13.
- [REFERENCE CONCEPTUAL SITE MODEL AND PLAN VIEW MAP]

In-situ Thermal Treatment

- SEE: Steam Enhanced Extraction
- DUS: Dynamic Underground Stripping
- ERH: Electrical Resistance Heating
- SPH™: Six Phase Heating
- ET-DSP™: Electro-Thermal Dynamic Stripping Process
- RF: Radio Frequency
- ISTD™: In-situ Thermal Desorption



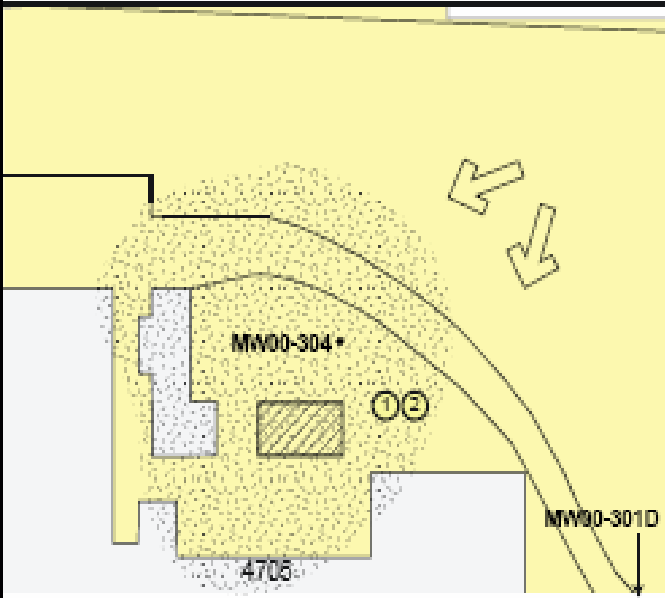
SUMMARY OF KEY CSM UNCERTAINTIES

- ① Quantity of TCE used and released to the environment
- ② Presence of major secondary sources of contamination
- ③ Presence of NAPL
- ④ Vertical extent of groundwater contamination

NOTES:
1. Locations and scales are approximate.



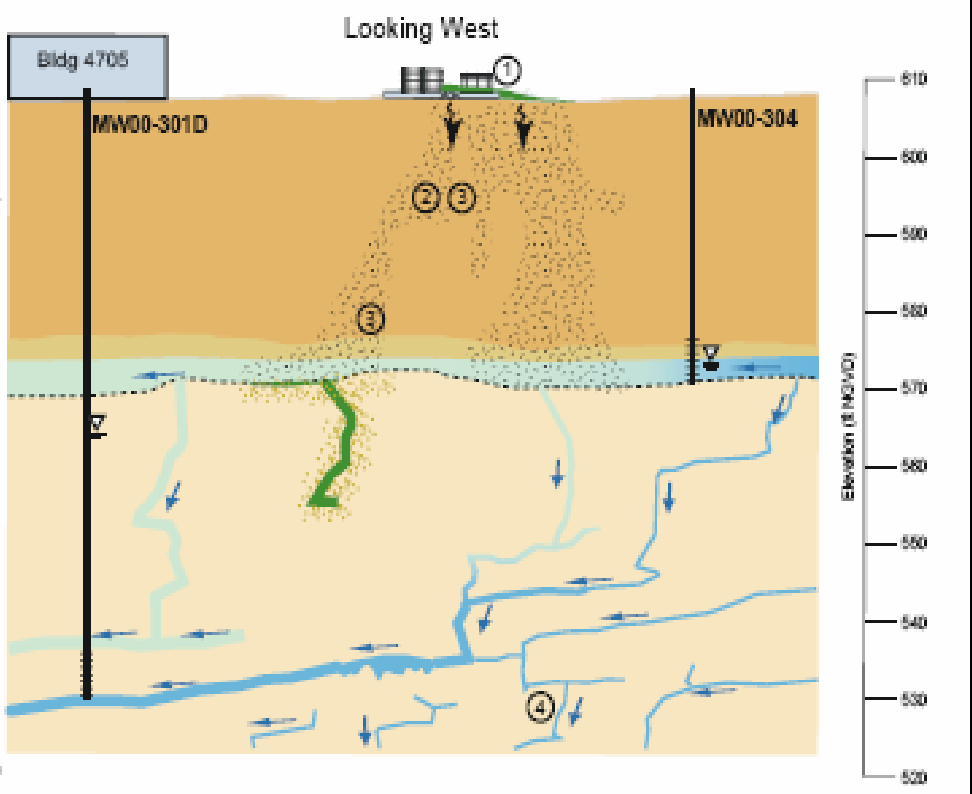
SA-13 Area - Aerial View



SA-13 Area - Plan View

- LEGEND
- Residuum Groundwater Monitoring Locations
 - ↙ Expected Direction of Shallow Groundwater Flow
 - Estimated Extent of TCE Detections
 - ⊙ Potential Secondary Source Material
 - ▨ Approximate Area of Proposed Interim Action

- LEGEND
- ▽ Groundwater Level
 - Monitoring Well
 - ▨ Monitoring Well Screened Interval
 - Local/Intermediate Groundwater Flow Patterns
 - ⬇ Former Contaminating Discharges
 - Dense Non-Aqueous Phase Liquids (DNAPLs)
 - ⊙ Potential Secondary Source Material
 - ⋯ Diffusion in Bedrock Fractures and Matrix
 - Dissolved Groundwater Contamination
 - Background or Relatively Uncontaminated Groundwater
 - Karst Features and Conduits
 - Bedrock (Clays and Silts with Lenses of Sands, Gravels)
 - Transitional Interval (Saturated)
 - Tuscaloosa-FL Payne Limestone
 - Approximate Top of Bedrock Surface

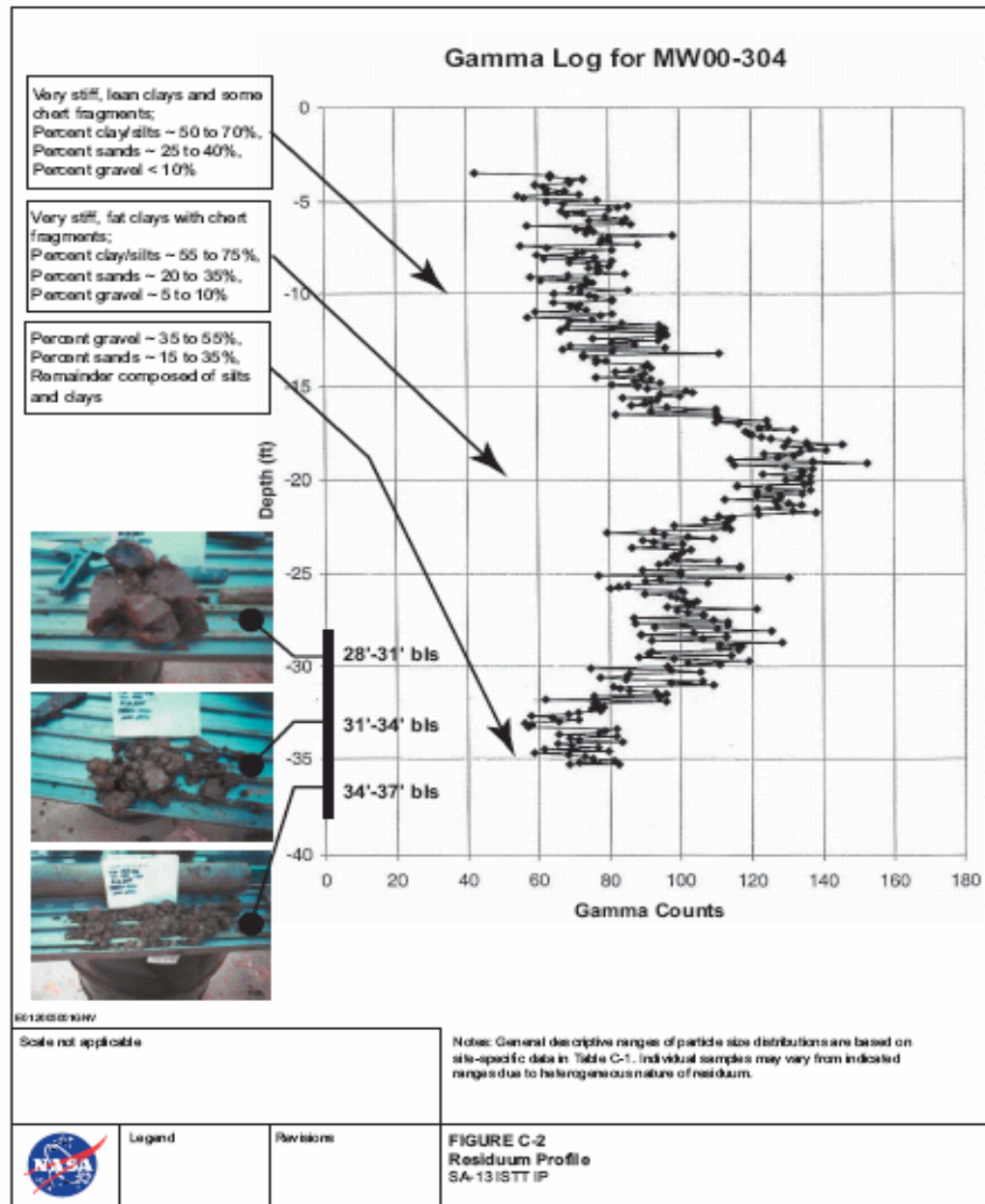


SA-13 Area - Generalized Cross-Section

SA-13 Lithology

- Regional subsurface lithology consists of weathered clayey residuum overlying karst limestone bedrock:
 - Groundwater occurs in the residuum and bedrock units;
 - Connectivity between units is variable across MSFC;
 - Flow is seasonally affected by downgradient surface water; and
 - Discharges through springs and seepage areas
- Subsurface conditions at SA-13 consist of approximately 35 feet of clayey residuum that transitions to bedrock through a 5-foot thick saturated zone:
 - The water-bearing zone is composed of gravel, sand, silt and clay which overlies weathered limestone bedrock.
 - Permeability of the residuum increases with depth.
- [REFERENCE GAMMA LOG FROM MW00-304]

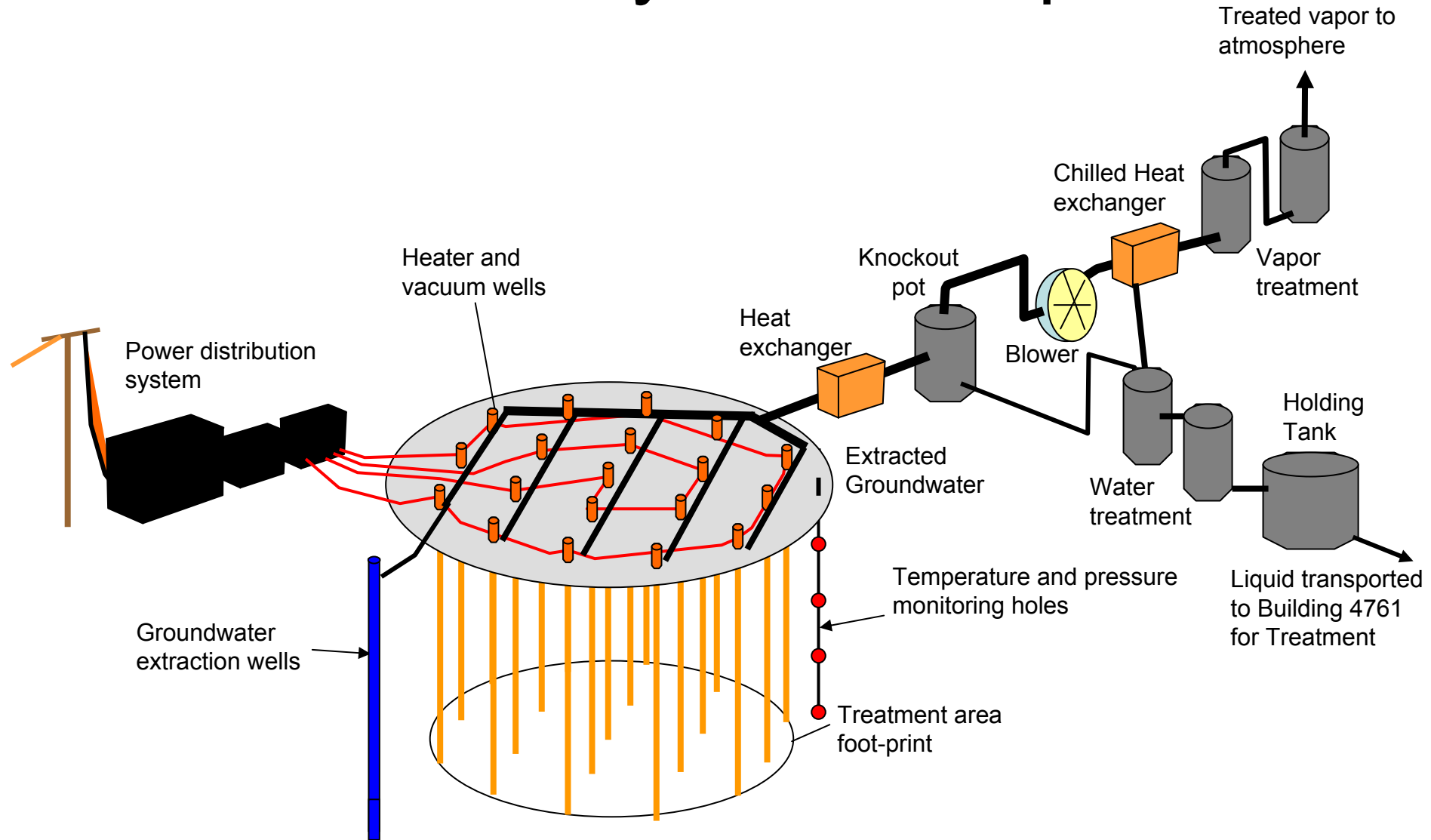
Residuum Profile...continued



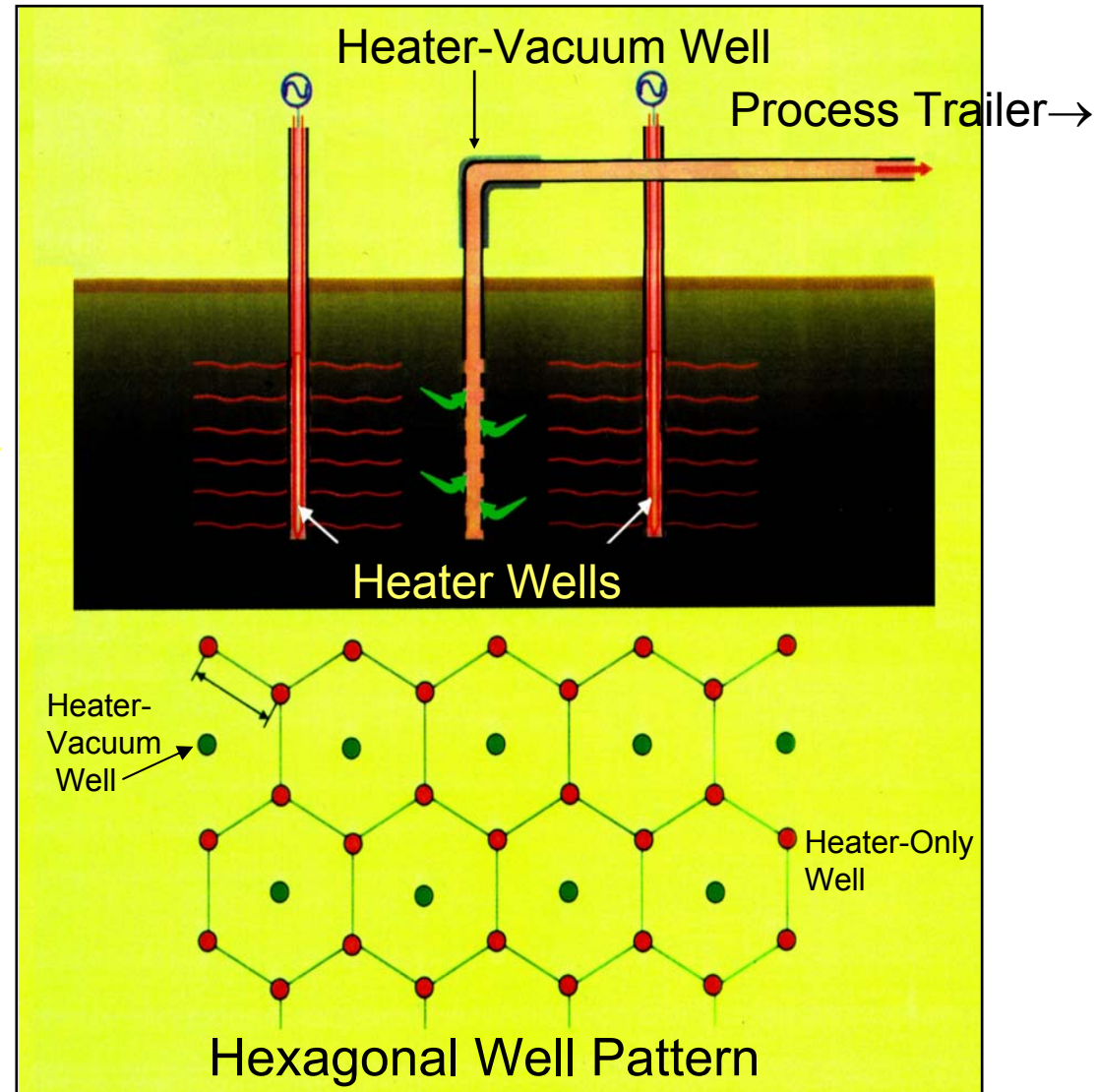
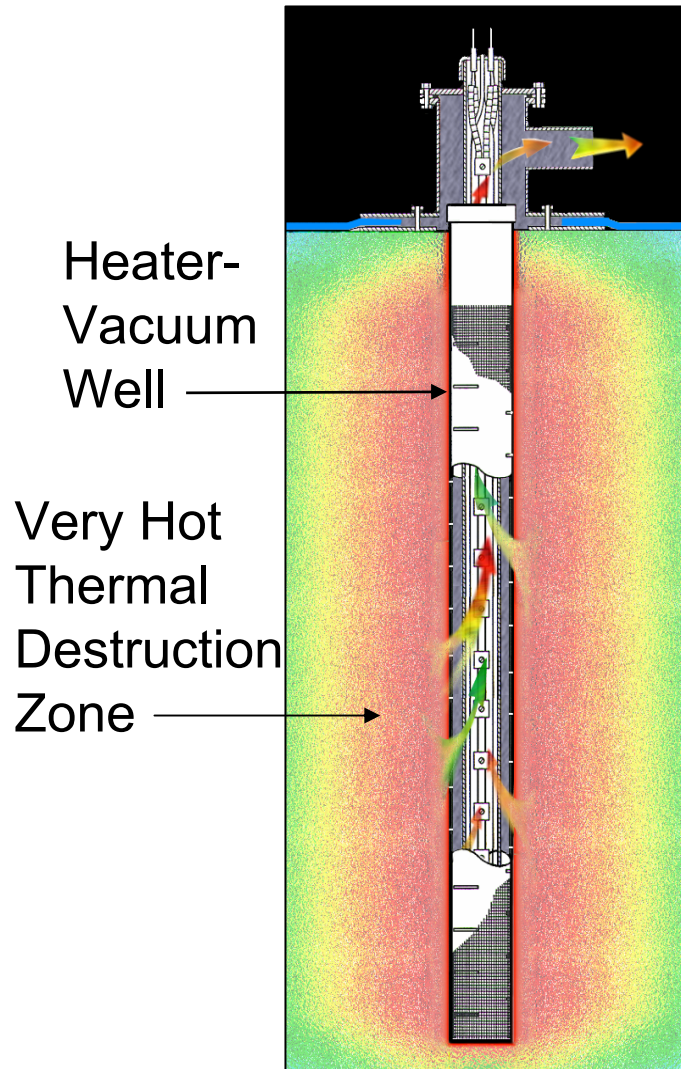
SA-13 In-Situ Thermal TS

- Implement ISTT in “hot spot” of source area to assess technology treatment capability
- In-situ Thermal Desorption (ISTD) process was selected for ISTT demonstration
- ISTD process originally developed by SHELL and licensed to TerraTherm®
 - electrical subsurface heating by thermal conduction
 - concurrent extraction of vapor and groundwater
 - ex-situ treatment of extracted fluids
- [Reference ISTD FIGURES]

SA-13 ISTD System Components



ISTD Overview

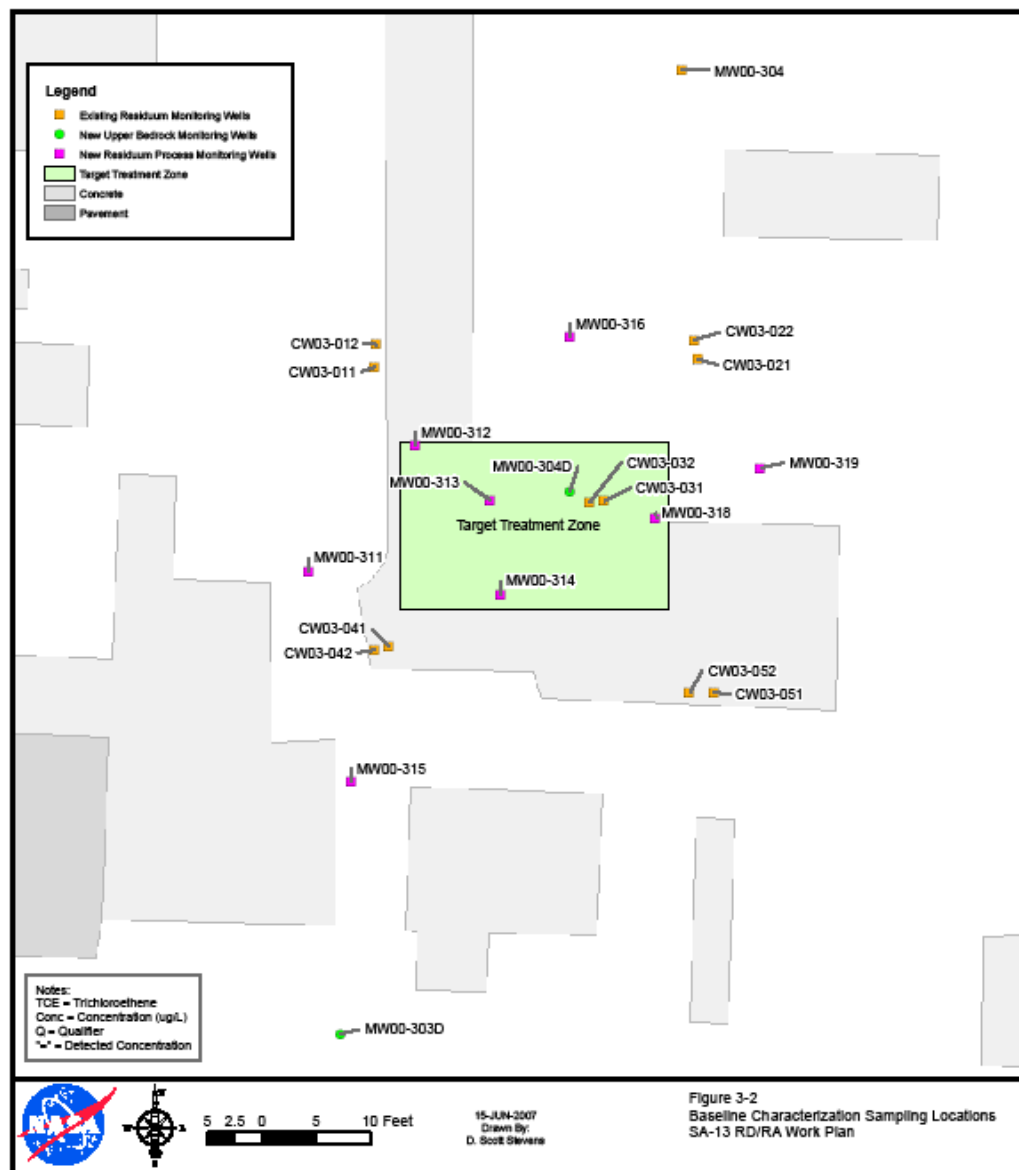


Heaters



SA-13 In-Situ Thermal TS

- Target treatment zone (TTZ) delineation:
 - Treatment area of approximately 500 square feet.
 - Vertical interval from 15' to 42' ft below land surface including 5 feet into underlying bedrock.
- Agencies suggested ISTT implementation as a CERCLA interim action under an Interim Record of Decision (IROD).
- Primary performance objective
 - Reduce estimated mass and average concentrations of TCE in TTZ soil and groundwater by 80% or greater.
- [Reference SITE MAPS/TTZ FIGURES]



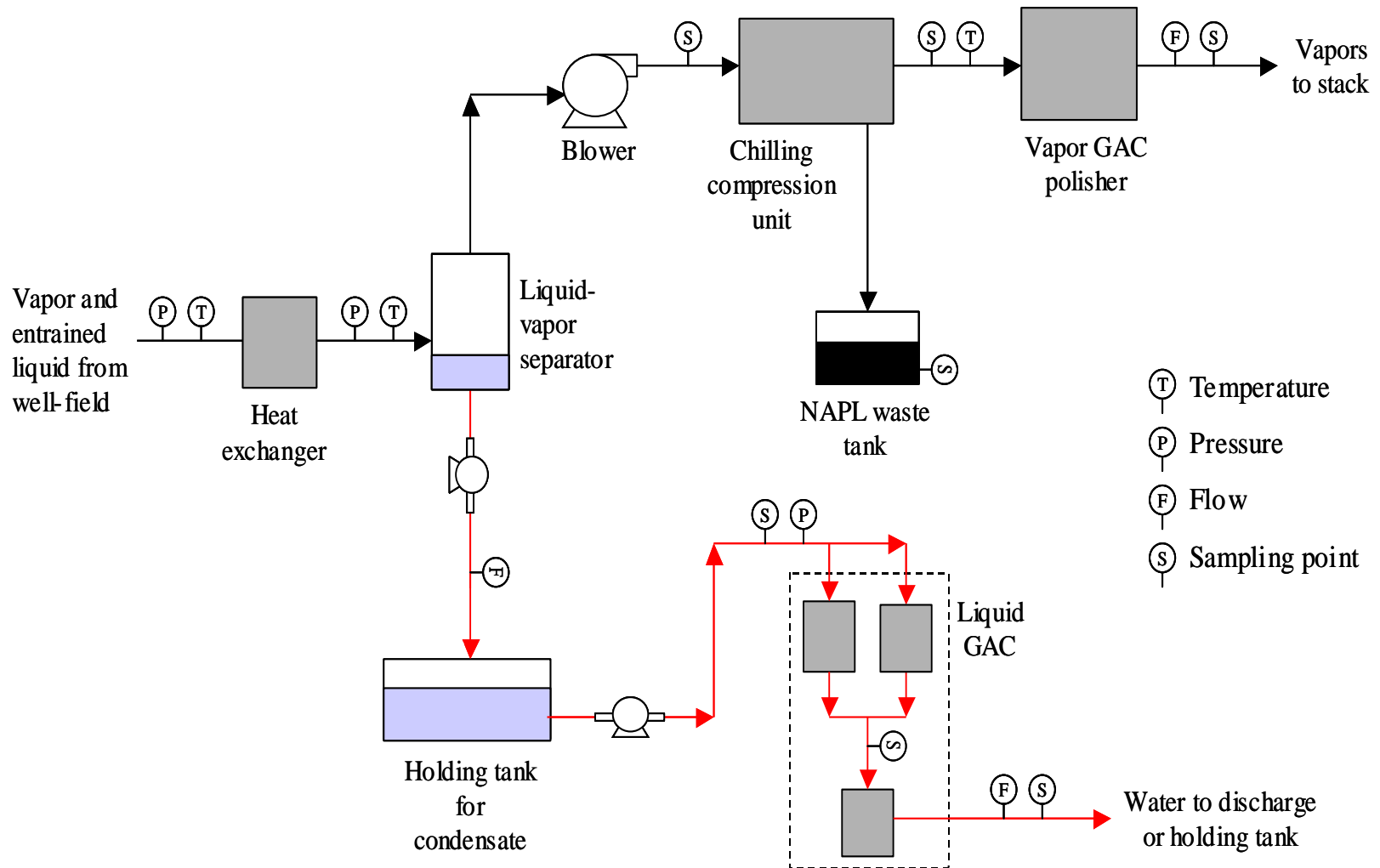
SA-13 ISTD Wellfield Layout

- 10 Heater-only wells
- 8 Heater/vapor recovery wells
- 4 Multiphase fluid extraction wells
- 9 Process monitoring wells
 - Pressure
 - Temperature (7 discrete intervals from 12 to 42 feet below ground surface)
- 8 Groundwater performance monitoring wells
 - 6 residuum
 - 2 bedrock
- [REFERENCE WELL FIELD LAYOUT PHOTO]

SA-13 Well Field

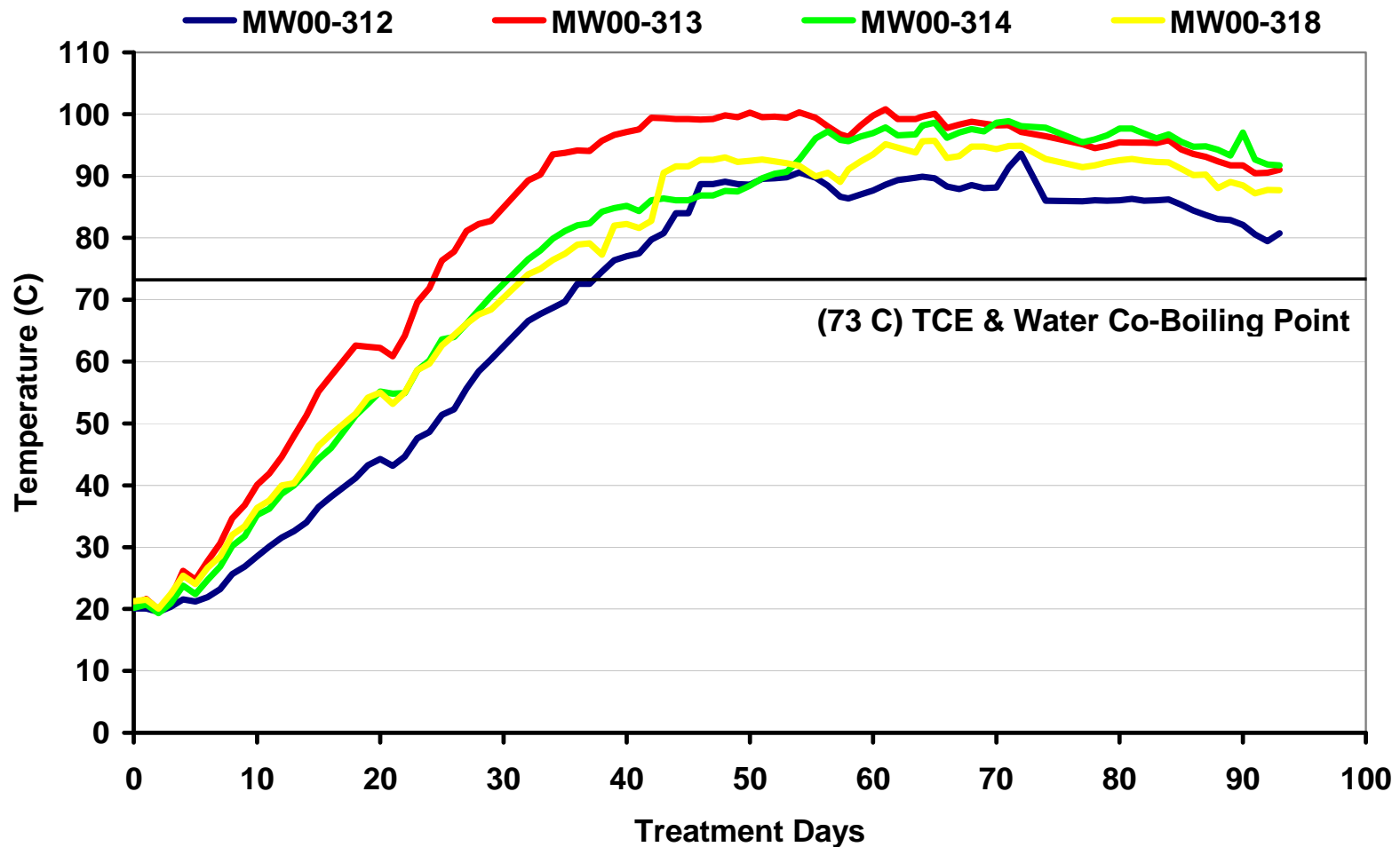


ISTD Process and Instrumentation

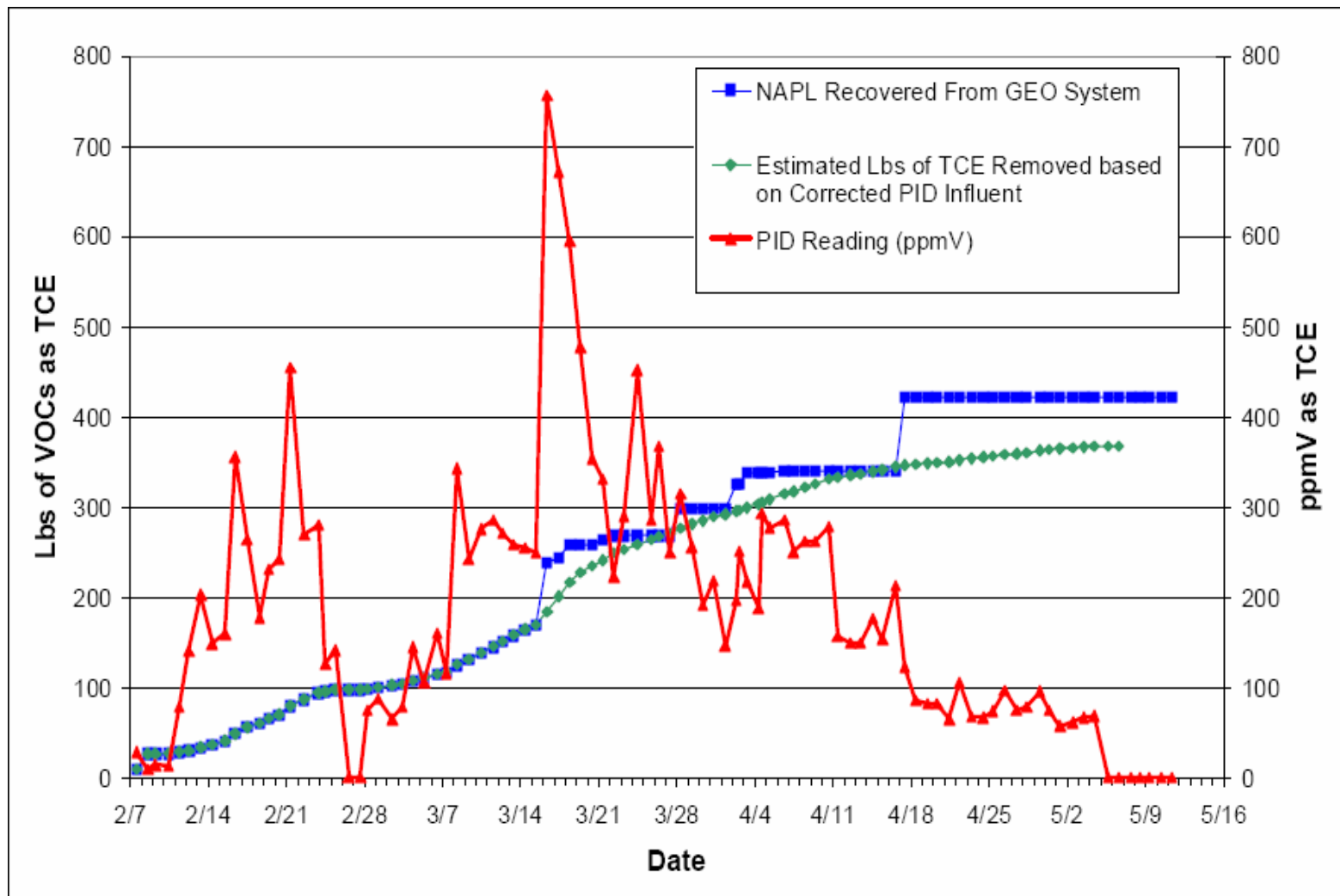


Treatment Zone Temperature

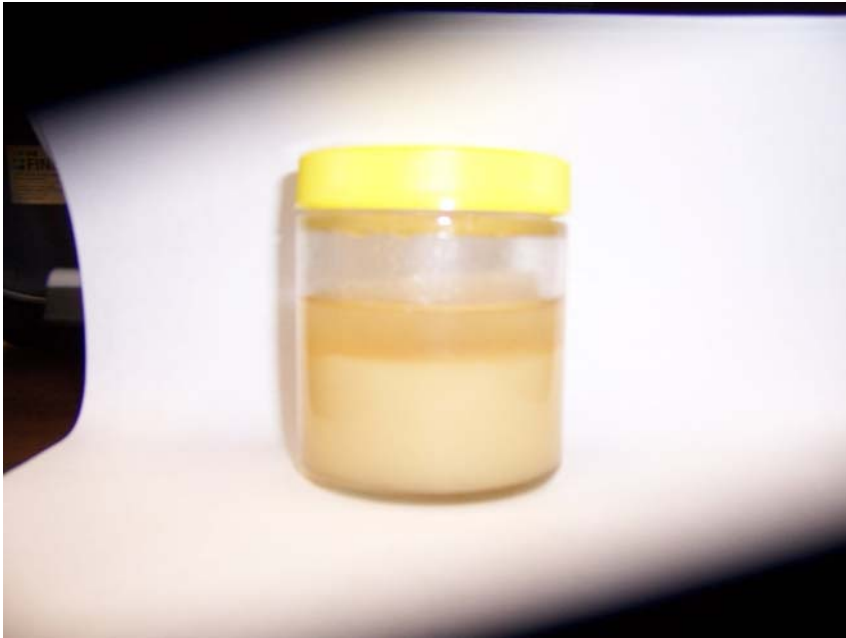
Average Treatment Zone Temperature as a Function of Time



SA-13 System Removals

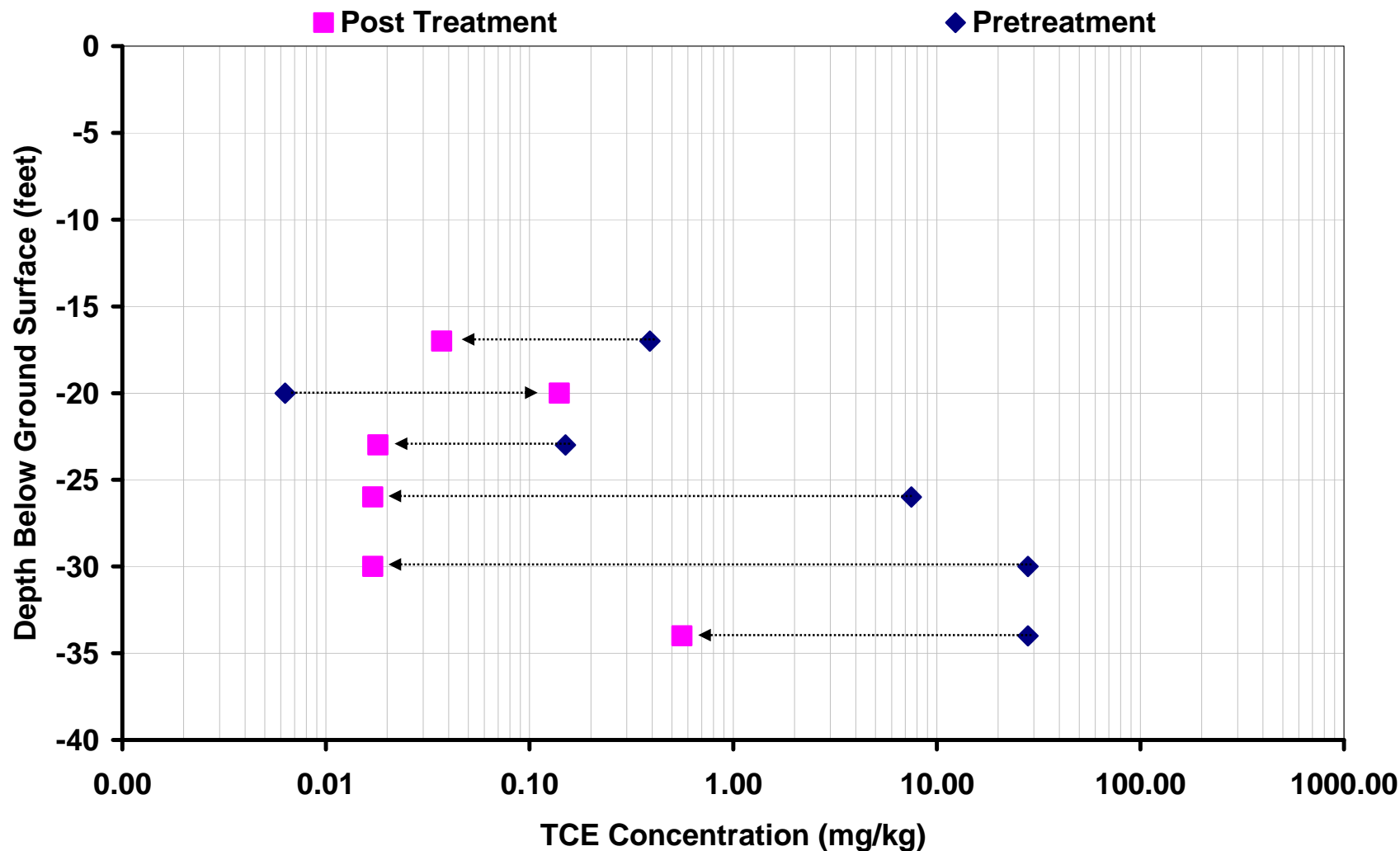


SA-13 DNAPL (typical photos)



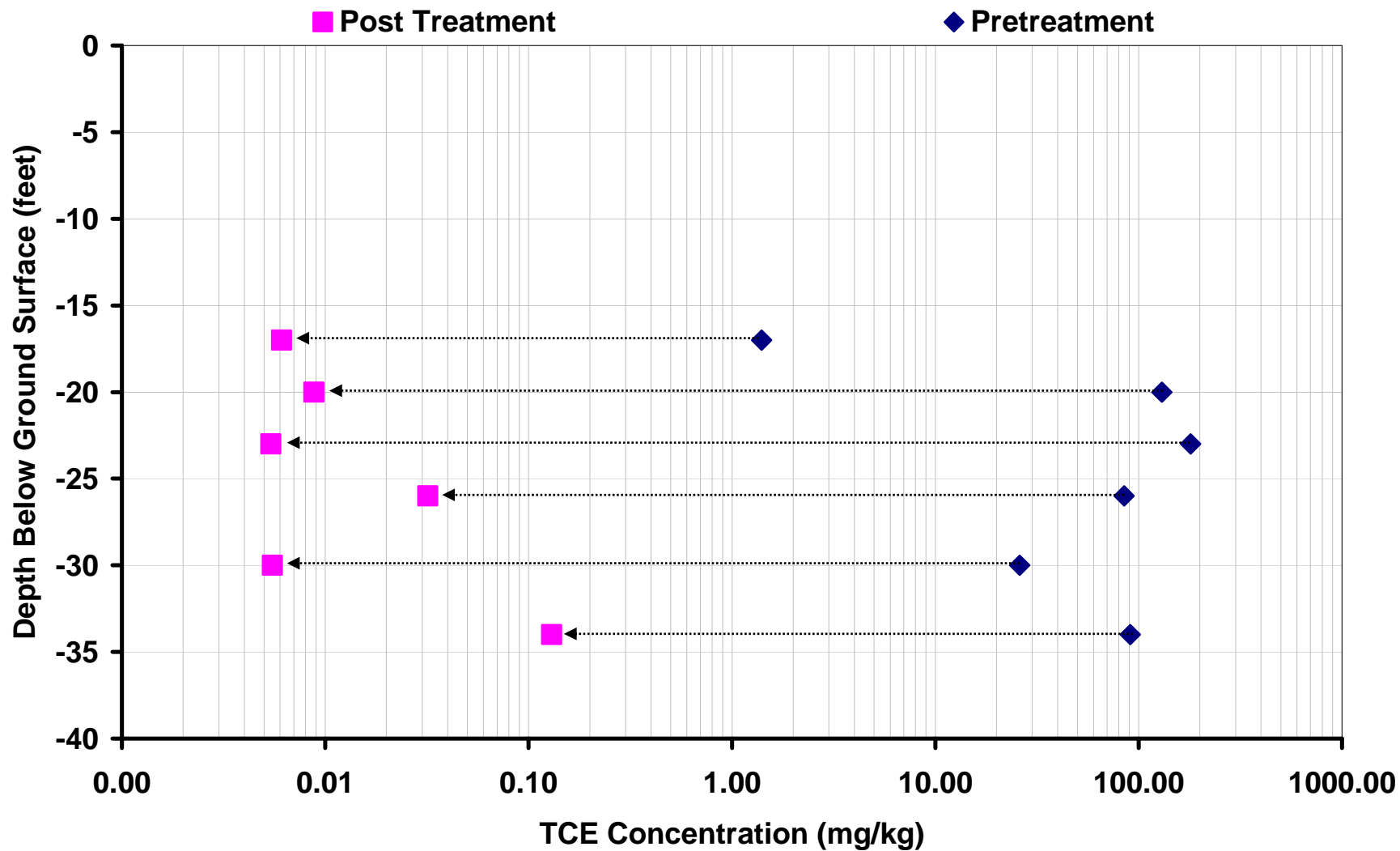
Treatment Results 1

Soil Sample Results MW00-312 / SB05-244



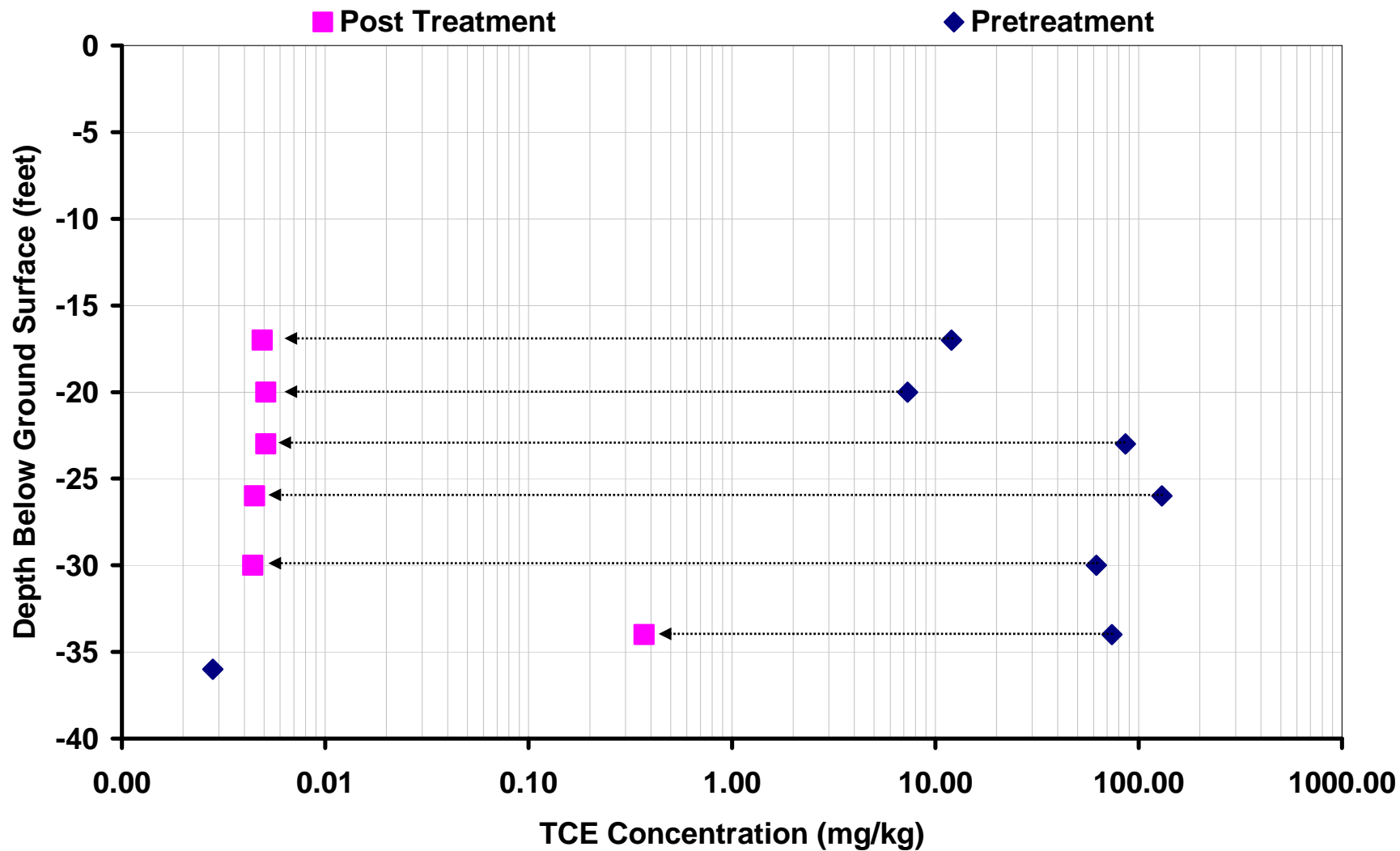
Treatment Results 2

Soil Sample Results MW00-318 / SB05-247



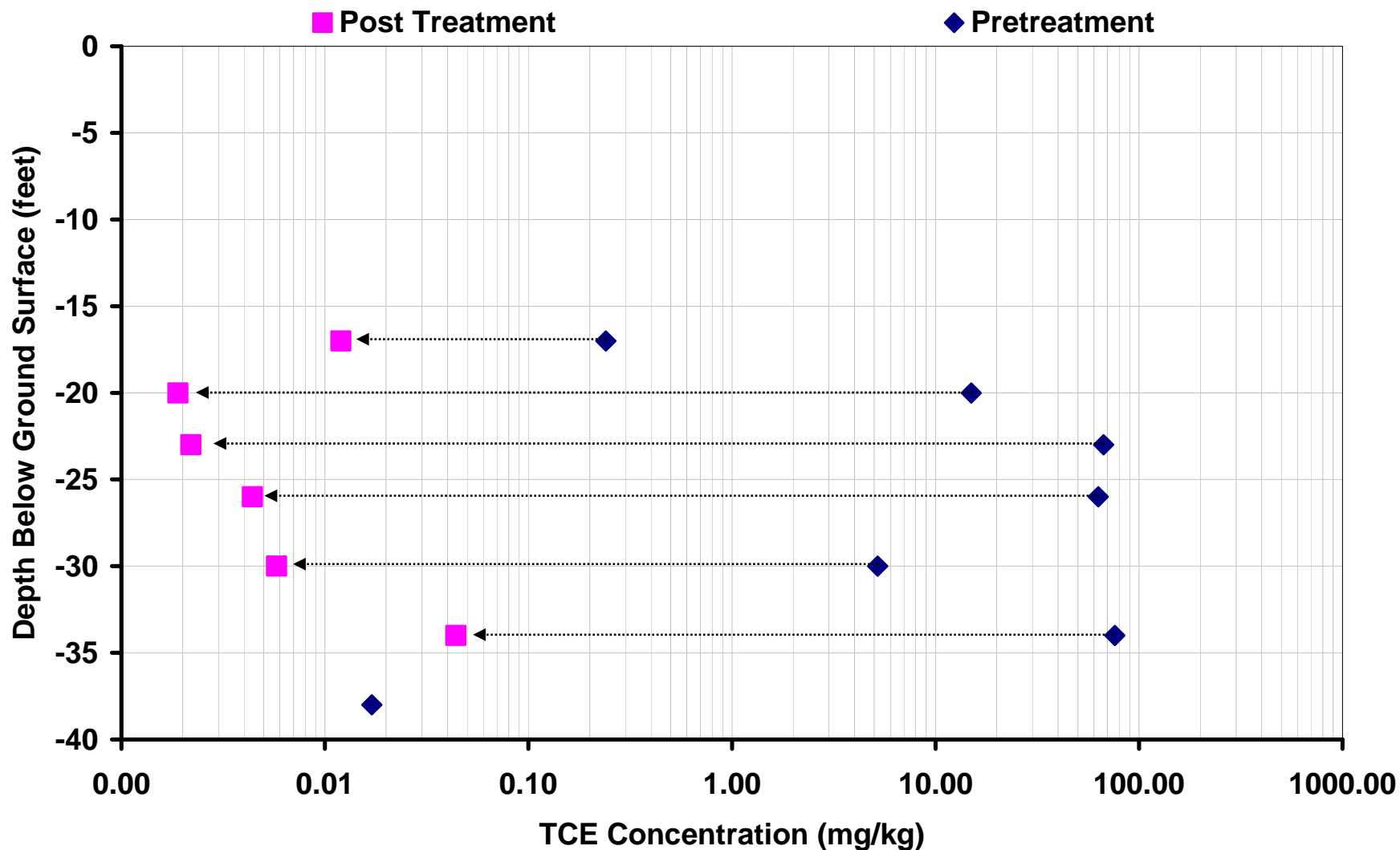
Treatment Results 3

Soil Sample Results MW00-314 / SB05-246



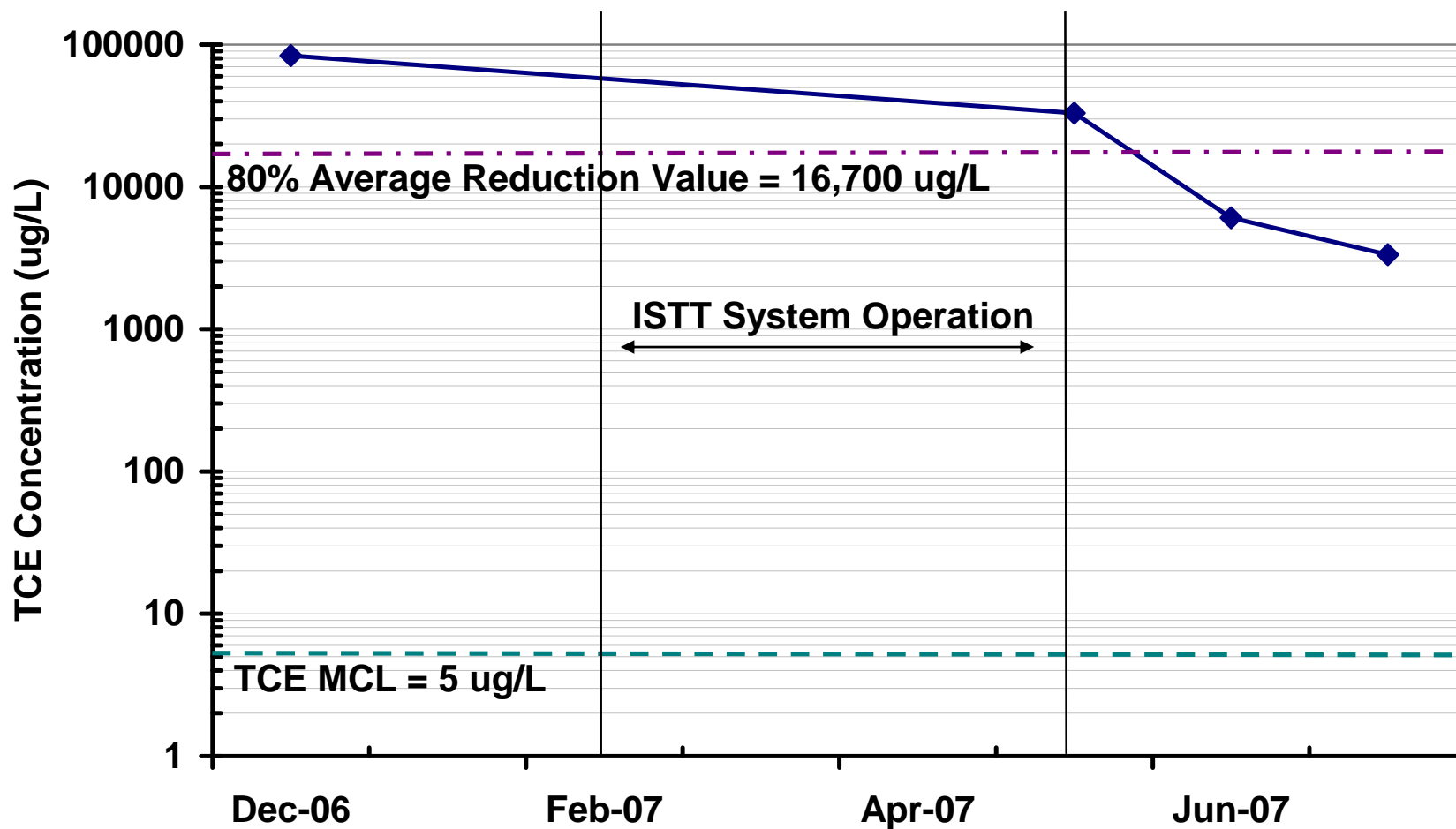
Treatment Results 4

Soil Sample Results MW00-313 / SB05-245



Treatment Results 5

Treatment Zone Average Groundwater Concentration



SA-13 TCE Removal Summary

Average Results	Residuum Media	
	Soil	Groundwater
Pre-Treatment Concentrations	57.4 mg/kg	77,860 µg/l
Pre-Treatment Mass	39.1 lbs	26.3 lbs
Post-Treatment Concentrations	0.05 mg/kg	2,870 µg/l
Post-Treatment Mass	0.09 lbs	5.4 lbs
Concentration Reduction	99.9 %	96.3 %
Estimated Mass Reduction	99.8 %	~ 80%

Summary

- The Interim Action removed approximately 400 pounds of TCE.
- First application of ISTT at MSFC and in the state of Alabama.
- Interim remedial action objectives and goals established for ISTT at SA-13 were achieved.
- Technology proved highly effective for:
 - source area mass reduction;
 - chlorinated solvent removal from the saturated and unsaturated residuum; and
 - treatment of heterogeneous subsurface environments.